MAX6759:
Safety Application Note

Failure–In–Time, Failure Mode Distribution and Pin Failure Mode and Effects Analysis

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Contents

1 | Overview

The scope of this document is to provide a report on MAX6759 to support in functional safety designs. This contains:

- Failure-In-Time (FIT) rates of the component calculated in accordance with the industry reliability standards
- Failure Mode Distribution of the device (FMD)
- Pin Failure Mode and Effects Analysis (Pin FMEA)

General Description

The MAX6759 is a low-power window detector designed to monitor system voltages for undervoltage (UV) and overvoltage (OV) conditions. It offers adjustable thresholds from 0.9V to 5V with a selectable ±5%, ±10%, or ±15% window voltage for precise monitoring and provide independent $\overline{\text{UV}}$ and $\overline{\text{OV}}$ outputs available in open-drain configuration.

Additional features include delay timing options (20µs, typ or 100ms, min), and a manual reset input. This device is available in SOT23 packages, and is specified over the extended temperature range of -40°C to +125°C.

Table 1-1 Product Description

Part Number	Primary Function	System Function
MAX6759	Low-power window detector	Monitor the System Supply Voltage and assert $\overline{\text{UV}}$ if it is below a certain threshold (UV), or assert $\overline{\text{OV}}$ if it is above a certain threshold (OV).

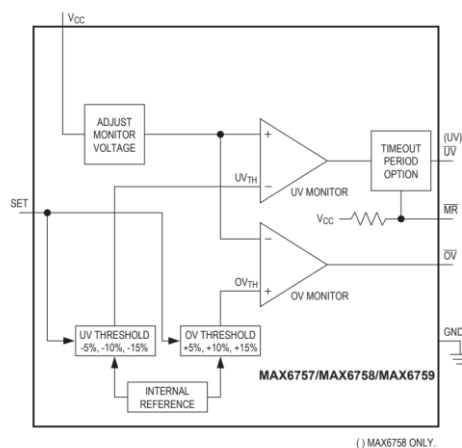Figure 1-1 shows the product specific block diagram of MAX6759.

Figure 1-1 MAX6759 Block Diagram

MAX6759 was developed following a quality-managed development process in compliance with ISO 9001 quality management system standards but was not developed in compliance with IEC61508 safety standard. The associated certificates are available on Quality Certificates | Analog Devices.

Table 1-2 Applicable Assumptions

The following assumptions were made in deriving the FMD and Pin FMEA.

Case	Assumption	Description
1	SET Pin Connected to GND	±5% OV/UV window tolerance
2	SET Pin Connected to VCC	±10% OV/UV window tolerance
3	SET Pin Connected to VCC/2	±15% OV/UV window tolerance

2 | Functional Safety Failure-In-Time (FIT) Rates

This section offers specific details on the base functional safety failure-in-time (FIT) rates for MAX6759, according to SN29500, IEC 62380 and accelerated testing conditions of HTOL. It also identifies the relevant component category for each standard, allowing customers to compute their own failure rates.

- Table 2-1 provides FIT rates according to SN29500
- Table 2-2 provides FIT rates according to IEC 62380
- Table 2-3 provides FIT rates according to HTOL

The FIT rates of MAX6759 based on SN29500 for a specific industrial mission profile is detailed below:

Table 2-1 Functional Safety Component FIT Rate According to SN29500

SN29500 Industrial Mission Profile	FIT (Failures Per 10^9 Hours)
Predicted Component FIT Rate	40.03

- Mission Profile: 20 years constant operation at 55°C temperature
- Climate type: World-wide (Table 8)
- Operating Voltage (max): 6V
- Power Dissipation: 0.18mW
- Theta-JA: 115°C/W
- Substrate Material: FR4
- EOS FIT rate assumed: 0 FIT
- Part is sensitive to drift

Note 1: For applications requiring a different mission profile, the following information can be used to calculate the base FIT rate based on SN29500.
- o SN29500 part and section: Part 2/Section 5 and ASICs
- o Sub-category: CMOS, BiCMOS
- o Integration Density: 50-5k

The FIT rates of MAX6759 based on IEC62380 for a specific industrial mission profile is detailed below:

Table 2-2 Functional Safety Component FIT Rates According to IEC62380

IEC62380 Industrial Mission Profile	FIT (Failures Per 10^9 Hours)
Total Component FIT Rate	5.23
Die FIT Rate	5.09
Package FIT Rate	0.14

Note 2: For applications requiring a different mission profile, the following information can be used to calculate the base FIT rate based on IEC62380.
- o FIT rate calculation model: Section 7.3.1, refer to Mathematical Model
- o IEC62380 part and section for die FIT rate: Table 16, MOS ASIC circuits, Full Custom
- o Production year for die FIT rate: 2004
- o Integration Density: 50-5k
- o IEC62380 part and section for package FIT rate: Table 17b, Two rows connections packages
- o Package type: SOT23 6 pins, length: 2.9mm, width: 1.62mm, pitch: 0.95mm
- o Interface device (EOS relevant): No

The FIT rates of MAX6759 based on accelerated testing conditions of HTOL is detailed below:

Table 2-3 Functional Safety Component FIT Rates According to HTOL Testing

Confidence Level	FIT (Failures Per 10^9 Hours)
70%	2.21
90%	4.24
95%	5.51
99%	8.47

Note 3: The FIT rates for various confidence levels were determined through HTOL reliability studies, utilizing the Arrhenius equation for acceleration assuming a chi-square distribution using the following test parameters:
- o Sample size: 7,563
- o Number of Failures: 0
- o Activation Energy: 0.7eV
- o Raw Device Hours: 7,059,016
- o Accelerated Temperature: 55°C
- o Equivalent Accelerated Device Hours: 543,565,635

3 | Failure Mode Distribution (FMD)

The failure mode distribution includes all relevant failure modes of the product function as defined in the product description.

Table 3-1 to Table 3-3 show the failure mode distribution estimations for MAX6759 as derived from the component die area ratio and complexity, and from engineering expertise. Refer to Table 1-2 for the applicable assumptions.

Since some failures had no effect and do not contribute to any failure mode, the total percentage of the Failure Mode Distribution would not add up to 100%. Correction factors (CF) were applied to the distributions to account for failures with no effect on the system.

System Function

- Monitor the System Supply Voltage and assert $\overline{UV}$ if it is below a certain threshold (UV), or assert $\overline{OV}$ if it is above a certain threshold (UV).

Table 3-1 Case 1: Failure Mode Distribution (CF = 1.48)

Failure Modes	Failure Mode Distribution
Part stuck with UV asserted	20%
Part stuck with OV asserted	12%
Part does not assert UV	27%
Part does not assert OV	27%
UV triggered early	4%
OV triggered early	4%
UV triggered late	3%
OV triggered late	3%

Table 3-2 Case 2: Failure Mode Distribution (CF = 1.55)

Failure Modes	Failure Mode Distribution
Part stuck with UV asserted	21%
Part stuck with OV asserted	9%
Part does not assert UV	27%
Part does not assert OV	31%
UV triggered early	4%
OV triggered early	4%
UV triggered late	2%
OV triggered late	2%

Table 3-3 Case 3: Failure Mode Distribution (CF = 1.44)

Failure Modes	Failure Mode Distribution
Part stuck with UV asserted	20%
Part stuck with OV asserted	8%
Part does not assert UV	24%
Part does not assert OV	28%
UV triggered early	8%
OV triggered early	8%
UV triggered late	2%
OV triggered late	2%

4 | Pin Failure Mode and Effects Analysis (Pin FMEA)

This section presents the Pin Failure Mode and Effects Analysis (Pin FMEA) for MAX6759. The failure modes discussed in this section encompass the common pin-by-pin failure scenarios:

Case 1 - SET pin connected to GND:
- Pin short-circuited to supply (see Table 4-1)
- Pin short-circuited to GND (see Table 4-2)
- Pin open-circuited (see Table 4-3)
- Pin short-circuited to adjacent pins (see Table 4-4)

Case 2 - SET pin connected to VCC:
- Pin short-circuited to supply (see Table 4-5)
- Pin short-circuited to GND (see Table 4-6)
- Pin open-circuited (see Table 4-7)
- Pin short-circuited to adjacent pins (see Table 4-8)

Case 3 - SET pin connected to VCC/2:
- Pin short-circuited to supply (see Table 4-9)
- Pin short-circuited to GND (see Table 4-10)
- Pin open-circuited (see Table 4-11)
- Pin short-circuited to adjacent pins (see Table 4-12)

Figure 4-1 illustrates the pin diagram for MAX6759. Refer to the product datasheet for a detailed description of each pin's function.
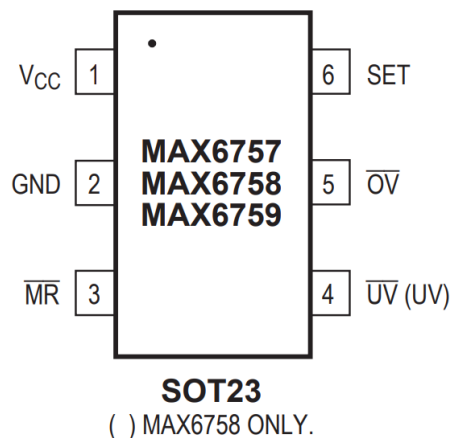

Figure 4-1. MAX6759 Pin Diagram

Below are the usage assumptions and device configuration considered for the Pin FMEA, based on the Typical Application Circuit, unless otherwise noted:

- The $\overline{OV}$ and $\overline{UV}$ pins are active-low reset output available in either open-drain or push-pull configuration.
- In the open-drain version, the $\overline{OV}$ and $\overline{UV}$ pins are connected to a 10kΩ pull-up resistor.
- The operating voltage range (VCC) is from 1.0V to 6.0V, and the operating temperature range (T_A) is from -40°C to +125°C.

Table 4-1 Case 1: Pin FMEA for MAX6759 Pins Short-Circuited to Supply

Pin no.	Pin Name	Effect of Failure Mode
1	VCC	No effect
2	GND	Part not functional
3	$\overline{MR}$	Part does not respond to $\overline{MR}$ assertion but can still detect supply UV
4	$\overline{UV}$	$\overline{UV}$ always high
5	$\overline{OV}$	$\overline{OV}$ always high
6	SET	Part not functional

Table 4-2 Case 1: Pin FMEA for MAX6759 Pins Short-Circuited to GND

Pin no.	Pin Name	Effect of Failure Mode
1	VCC	Part not functional
2	GND	No effect
3	$\overline{MR}$	$\overline{UV}$ always low
4	$\overline{UV}$	$\overline{UV}$ always low
5	$\overline{OV}$	$\overline{OV}$ always low
6	SET	OV threshold always 5%, UV threshold always -5%

Table 4-3 Case 1: Pin FMEA for MAX6759 Pins Open-Circuited

Pin no.	Pin Name	Effect of Failure Mode
1	VCC	Part not functional
2	GND	Part not functional
3	$\overline{MR}$	Part does not respond to $\overline{MR}$ assertion but can still detect supply UV
4	$\overline{UV}$	Unreliable $\overline{UV}$ output
5	$\overline{OV}$	Unreliable $\overline{OV}$ output
6	SET	Indeterminate OV and UV thresholds. Unreliable $\overline{UV}$ and $\overline{OV}$ outputs

Table 4-4 Case 1: Pin FMEA for MAX6759 Pins Short-Circuited to Adjacent Pins

Pin no.	Pin Name	Shorted to	Effect of Failure Mode
1	VCC	GND	Part not functional
2	GND	$\overline{MR}$	$\overline{UV}$ always low
3	$\overline{MR}$	$\overline{UV}$	No effect
4	$\overline{UV}$	$\overline{OV}$	$\overline{UV}$ and $\overline{OV}$ output assertion in OR logic
5	$\overline{OV}$	SET	$\overline{OV}$ always low
6	SET	VCC	Part not functional

Table 4-5 Case 2: Pin FMEA for MAX6759 Pins Short-Circuited to Supply

Pin no.	Pin Name	Effect of Failure Mode
1	VCC	No effect
2	GND	Part not functional
3	$\overline{MR}$	Part does not respond to $\overline{MR}$ assertion but can still detect supply UV
4	$\overline{UV}$	$\overline{UV}$ always high
5	$\overline{OV}$	$\overline{OV}$ always high
6	SET	OV threshold always 10%, UV threshold always -10%

Table 4-6 Case 2: Pin FMEA for MAX6759 Pins Short-Circuited to GND

Pin no.	Pin Name	Effect of Failure Mode
1	VCC	Part not functional
2	GND	No effect
3	$\overline{MR}$	$\overline{UV}$ always low
4	$\overline{UV}$	$\overline{UV}$ always low
5	$\overline{OV}$	$\overline{OV}$ always low
6	SET	Part not functional

Table 4-7 Case 2: Pin FMEA for MAX6759 Pins Open-Circuited

Pin no.	Pin Name	Effect of Failure Mode
1	VCC	Part not functional
2	GND	Part not functional
3	$\overline{MR}$	Part does not respond to $\overline{MR}$ assertion but can still detect supply UV
4	$\overline{UV}$	Unreliable $\overline{UV}$ output
5	$\overline{OV}$	Unreliable $\overline{OV}$ output
6	SET	Indeterminate OV and UV thresholds. Unreliable $\overline{UV}$ and $\overline{OV}$ outputs

Table 4-8 Case 2: Pin FMEA for MAX6759 Pins Short-Circuited to Adjacent Pins

Pin no.	Pin Name	Shorted to	Effect of Failure Mode
1	VCC	GND	Part not functional
2	GND	$\overline{MR}$	$\overline{UV}$ always low
3	$\overline{MR}$	$\overline{UV}$	No effect
4	$\overline{UV}$	$\overline{OV}$	$\overline{UV}$ and $\overline{OV}$ output assertion in OR logic
5	$\overline{OV}$	SET	$\overline{OV}$ always high
6	SET	VCC	OV threshold always 10%, UV threshold always -10%

Table 4-9 Case 3: Pin FMEA for MAX6759 Pins Short-Circuited to Supply

Pin no.	Pin Name	Effect of Failure Mode
1	VCC	No effect
2	GND	Part not functional
3	$\overline{MR}$	Part does not respond to $\overline{MR}$ assertion but can still detect supply UV
4	$\overline{UV}$	$\overline{UV}$ always high
5	$\overline{OV}$	$\overline{OV}$ always high
6	SET	OV threshold always 10%, UV threshold always -10%

Table 4-10 Case 3: Pin FMEA for MAX6759 Pins Short-Circuited to GND

Pin no.	Pin Name	Effect of Failure Mode
1	VCC	Part not functional
2	GND	No effect
3	$\overline{MR}$	$\overline{UV}$ always low
4	$\overline{UV}$	$\overline{UV}$ always low
5	$\overline{OV}$	$\overline{OV}$ always low
6	SET	OV threshold always 5%, UV threshold always -5%

Table 4-11 Case 3: Pin FMEA for MAX6759 Pins Open-Circuited

Pin no.	Pin Name	Effect of Failure Mode
1	VCC	Part not functional
2	GND	Part not functional
3	$\overline{MR}$	Part does not respond to $\overline{MR}$ assertion but can still detect supply UV
4	$\overline{UV}$	Unreliable $\overline{UV}$ output
5	$\overline{OV}$	Unreliable $\overline{OV}$ output
6	SET	Indeterminate $\overline{OV}$ and $\overline{UV}$ thresholds. Unreliable $\overline{UV}$ and $\overline{OV}$ outputs

Table 4-12 Case 3: Pin FMEA for MAX6759 Pins Short-Circuited to Adjacent Pins

Pin no.	Pin Name	Shorted to	Effect of Failure Mode
1	VCC	GND	Part not functional
2	GND	$\overline{MR}$	$\overline{UV}$ always low
3	$\overline{MR}$	$\overline{UV}$	No effect
4	$\overline{UV}$	$\overline{OV}$	$\overline{UV}$ and $\overline{OV}$ output assertion in OR logic
5	$\overline{OV}$	SET	$\overline{OV}$ stuck at VCC/2. Indeterminate $\overline{OV}$ output
6	SET	VCC	OV threshold always 10%, UV threshold always -10%

5 | Revision History

Revision	Revision Date	Description
A	September 2024	Initial Release

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